Kinematics Via Prototyping and CAD

This paper discusses the kinematics of a planar 4 bar mechanism. Specifically, the crank-rocker.

1 Paper Compatible Mock-Up

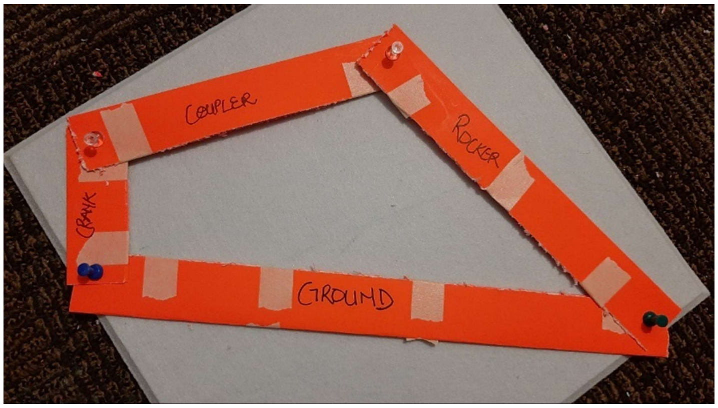

Figure 1 4 bar mechanism showing clearly all 4 links

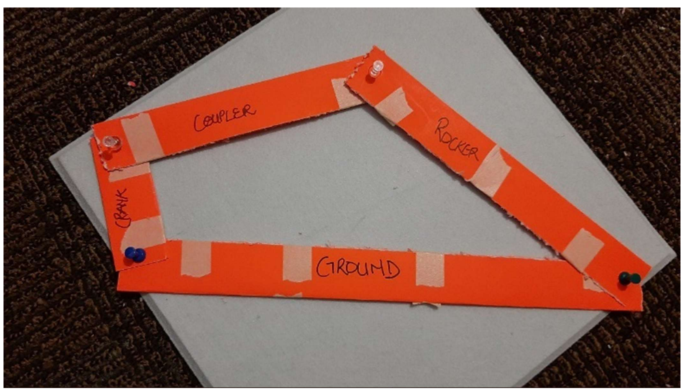

Figure 2 4 bar mechanism with crank moving towards the left

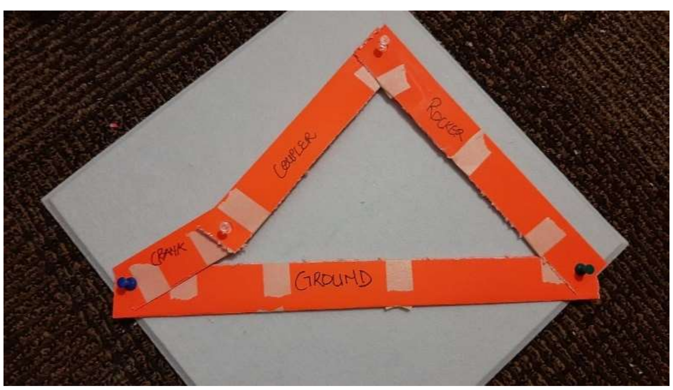

Figure 3 Rocker at maximum angle

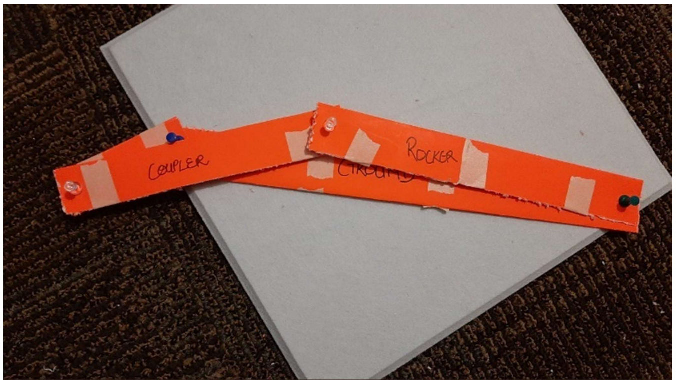

Figure 4 Rocker at minimum angle

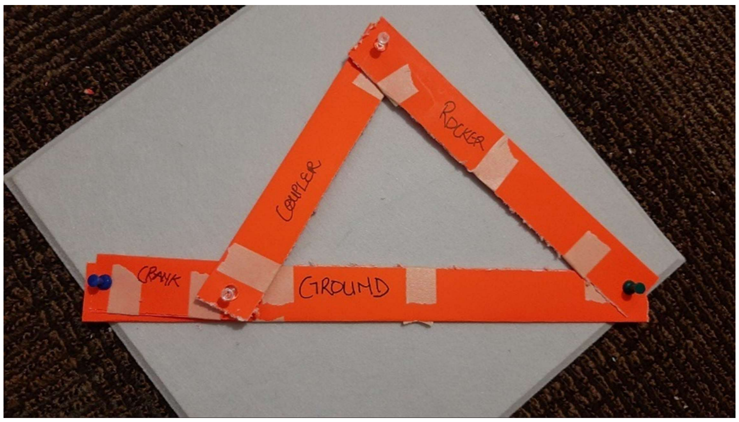

Figure 5 Mechanism with crank parallel to ground link

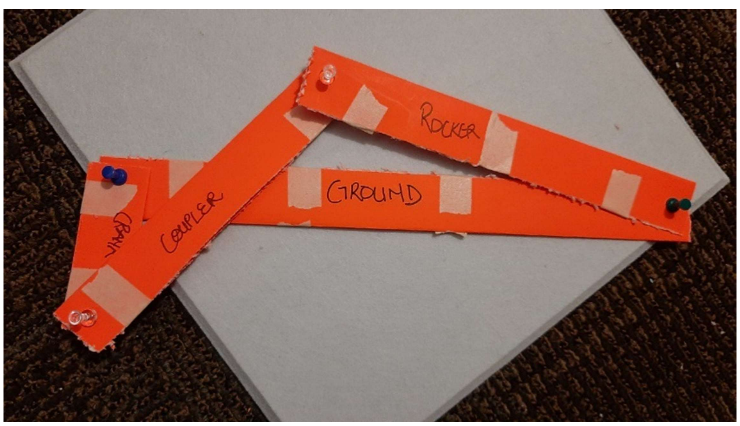

Figure 6 Crank almost perpendicular to base link

2 System representation

As indicated by [1], the system is a planar system as the axes of the 4 joints are parallel to each other. A pop-up representation of this mechanism would lie flat in one plane if the base and the crank were at 180 degrees from each other. This further supports the fact that this is a planar system.

3 SolidWorks Representation

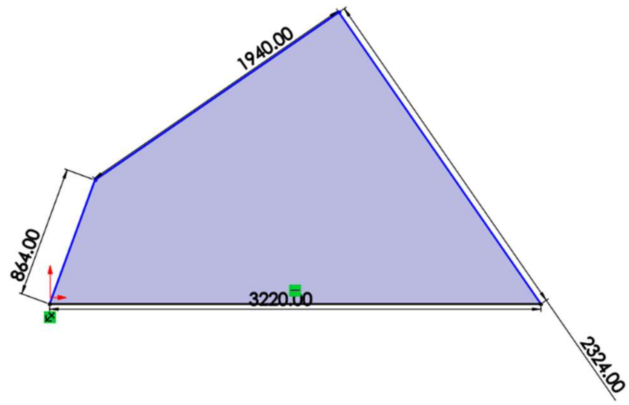

Figure 7 Solidworks sketch of 4 bar planar mechanism

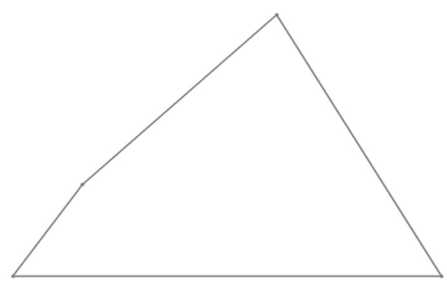

Figure 8 Rocker at maximum angle

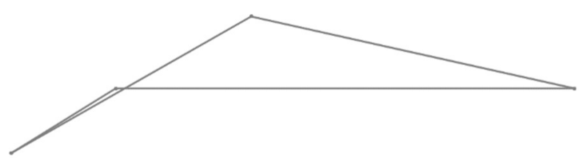

Figure 9 Rocker at minimum angle

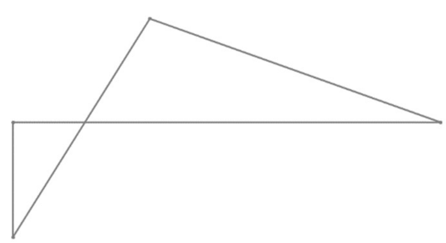

Figure 10 Crank orthogonal to base

4 Degrees of Freedom

I identified that the system had 1 degree of freedom. First, by subtracting the number of constraints from the number of unknowns. With 4 joints, the system could be defined by 4 vertices which results in 8 degrees of freedom. By constraining the base (4 constraints) and including 3 extra dimensional constraints to the other links, the degrees of freedom become 8-7=1.

In solidworks, adding a fixed angle between the crank and the base fully constrained the system.

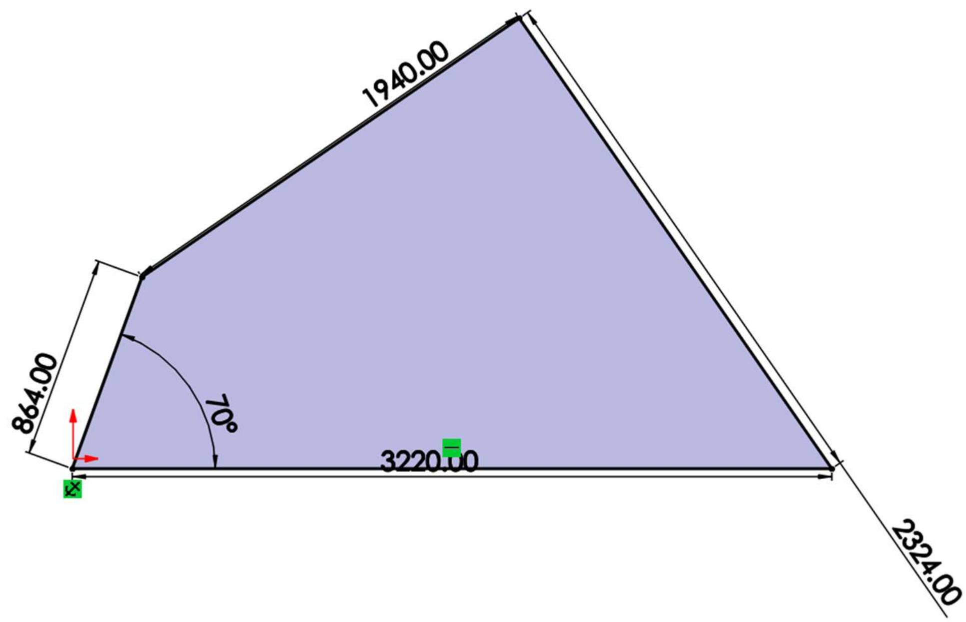

Figure 11 Fully constrained system

5 Input and Output

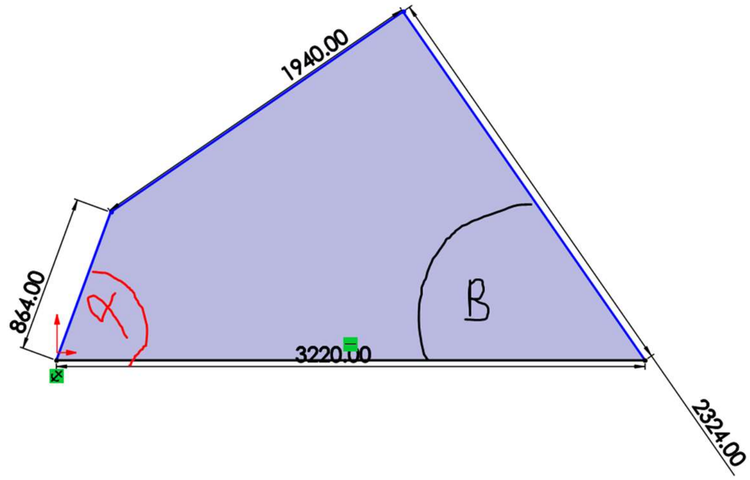

Figure 12 Input and Output of 4 bar mechanism

The mechanism has one input and one output for its one degree of freedom movement.

The input of the mechanism is the angle between the crank and the base link. Changing this angle drives the rocker to change its angle also. The angle between the rocker and the base (show and B in the figure) is the output of the mechanism.

6 Range of Motion

Part	Minimum Range of Motion	Max Range of Motion
Input	0 degrees	360 degrees
Output	13.22 degrees	58.01 degrees

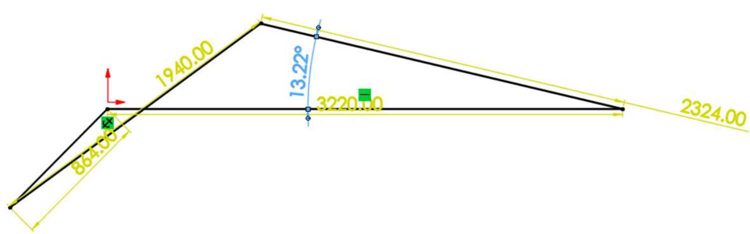

Figure 13 Minimum range of motion for output

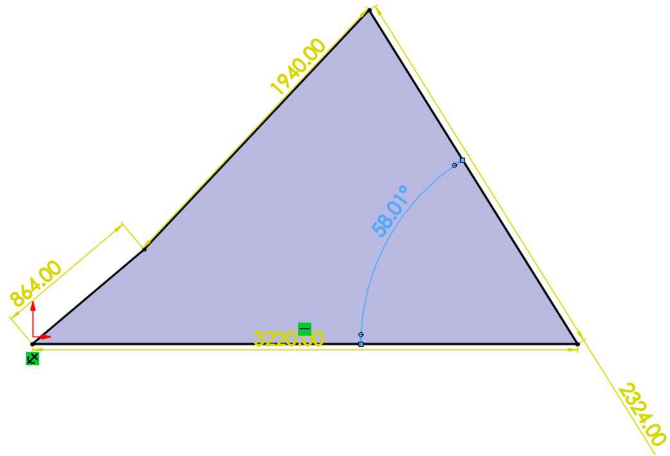

Figure 14 Maximum range of motion for output

Altering the angles by manually entering values provided fully defined systems at the two angles of minimum and maximum values above.

7 Discussion

7.1 Joint Motion

The crank-base joint rotates a fully 360 degrees. Given the constraints of folded paper, this issue can be addressed by using a layered mechanism to allow for free rotation about the revolute joint.

7.2 Singularities

The joint between the coupler and the crank presents a singularity when the rocker is moved from different starting positions of the crank. This is undesirable, however due to the fact that the input of the system is the crank-base angle, this singularity does not present a concern. The system need be configurated in a way that ensures input from the crank at all times to avoid this singularity.

7.3 Input-output relation

The input and output seem to have some sort of polynomial relationship. Increasing the input from 0 degrees slightly increases the output and then begins to decrease the output as the input continues to increase. A little after 180 degrees in the input causes the output to increase again. Actuation of the input will not be heavily affected as controlling it requires only one direction of motion at a time. The output changes in direction as the input increases.

7.4 Actuators

The crank-base joint will be a good spot to place an actuator that controls the output of the mechanism. The output of the mechanism could also be actuated, but this will be controlled solely by the input. With the exception of these two joints all other joints may not require actuation. At the moment, the team has not fully decided on a mechanism and mode of actuation but have considered the possibility of a spring-mass system. [2]

8 References

[1] B. G. Winder, S. P. Magleby, and L. L. Howell, "Kinematic Representations of Pop-Up Paper Mechanisms," *J. Mech. Robot.*, vol. 1, no. 2, Jan. 2009.

[2] G. Miller, *The motion dynamics of snakes and worms*, vol. 22. 1988.